DOCUMENT RESUME

ED 267 993 SE 046 517

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TITLE	Undergraduates Studying Science: Views on STS of Future Scientists and Non-Scientists.
INSTITUTION	Saskatchewan Univ., Saskatoon. Dept. of Curriculum Studies.
PUB DATE	86
NOTE	24p.; Paper presented at the Annual Meeting of the National Association for Research in Science Teaching (59th, San Francisco, CA, March 28 - April 1, 1986).
PUB TYPE	Reports - Research/Technical (143) -- Speeches/Conference Papers (150)
EDRS PRICE	MF01/PC01 Plus Postage.
DESCRIPTORS	*College Science; Comprehension; Higher Education; Science Education; *Student Attitudes; *Technology
IDENTIFIERS	*Canada; *Science and Society; Science Education Research

ABSTRACT

This paper is based on an analysis of a portion of data collected during a 6-month field study in a chemistry department in a Canadian university. Specifically, the views on the interaction among science, technology, and society (STS) held by undergraduates in this department were examined using a variation of VOSTS CDN-2. In addition, individual interviews with selected students were conducted. Results obtained from the VOSTS CDN-2 and from two areas explored during interviews (the nature of science and the role of science in society) indicate that the undergraduates are nearly identical to high school graduates in their understandings of the relationship between science, technology, and society. The number of university science courses taken appears to have had little effect on this understanding. Drawing prospective science teachers from this group presents STS teacher educators with a challenge. To prepare teachers to deal with STS issues, teacher educators must move beyond methods courses to remedy serious deficiencies in knowledge about the social context of science and technology. This task will likely be taken on by faculties of education and not faculties of science. (JN)

Information and Research Report

UNDERGRADUATES STUDYING SCIENCE: VIEWS ON STS OF FUTURE SCIENTISTS AND NON-SCIENTISTS

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A presentation to the 59th annual meeting of the National Association for Research in Science Teaching
San Francisco, CA, March 29, 1986.

INTRODUCTION

This paper is based on an analysis of a portion of the data collected during a six month field study in a chemistry department in a Canadian university. Specifically, the views on science-technology-society topics (STS) held by undergraduates in this department were examined using a variation of VOSTS CDN-2 (Aikenhead, Fleming & Ryan, 1986) as well as interviews with selected students. The student views addressed by this paper are those concerned with the interactions among science, technology, and society.

THEORETICAL BACKGROUND TO THE STUDY

The call for a re-emphasis in science education is well documented. The proposed focus, teaching science as a human endeavour, science-technology-society topics (STS) education, is supported by the National Science Teachers' Association (NSTA, 1982) and in the U.K. by the Association for Science Education (ASE, 1979). Project Synthesis included a STS group in its evaluation of science instruction in the United States (Piel, 1981). STS education is a principal recommendation of the Science Council of Canada (1984) and remains the focus of international symposia such as those held in Brisbane, December 1984, and Bangalore, August 1985, and the proposed symposium in Kiel, August 1987.

As a result of such international interest, a number of curriculum projects stressing the interaction of science with

technology and the social context have been initiated. These programs include: <u>Science in Society</u> (Lewis, 1981), <u>Science and Society Teaching Units</u> (Roberts, 1981), <u>Preparing for Tomorrow's World</u> (Iozzi, 1982), the PLON project (Eijkelhof & Kortland, 1982), <u>Science in the Social Context</u> (Solomon, 1983), and <u>Innovations: The Social Consequences of Science and Technology</u> (BSCS, 1984). These projects emerged from the belief that science education was not properly preparing students to function responsibly in a society which is pervasively affected by science and technology (Aikenhead, 1980; Bybee, 1985).

Such demands upon the science education enterprise create the expected strains. Attempts to define STS education continue. Debate (usually centered on views of the nature of science) about its proper placement within the enterprise is ongoing (Goode, Kromhout, Lawson & Renner, 1985; Bybee, 1985). Concern over the training of teachers who can teach STS topics has also arisen. It is these concerns which gave rise, in part, to the research described herein.

Debate centered on the nature of science revolves around two camps: positivists and constructionists. The latter position, which asserts that scientific knowledge is a product of social interaction rather than simply the laboratory, offers a useful model of science for STS education.

The data supporting the constructivist position are to be found in the social studies of science. A number of studies examine scientific work in its natural setting (Latour & Woolgar, 1979;

Knorr-Cetina, 1981; Lynch, 1985). Other studies focus on scientific communication, particularly speech acts and writing research articles. The former has been formalized as a study of scientific discourse (Mulkay & Gilbert, 1982a, 1984). The latter is often referred to as "the organization of persuasion through literary inscription" (Latour & Woolgar, 1979, p.88). This, coupled with studies of the practical reasoning of scientists (Law & Williams, 1982; Lynch, 1985) has offered further insights into scientific practice.

Despite this collection of studies concerning the functioning of science, little or no work has been done concerning the training experiences of those who plan to be scientists and those who, though studying sciences, have other occupational plans. It is from both of these groups that prospective science teachers are drawn. Little, if anything, is known about the normative beliefs which arise during training. The assumption is made that factual knowledge forms the basis of a decision in STS issues. Previous research (Fleming, 1985a, 1985b) has indicated that, for high school graduates, this is definitely not the case. Decisions about socio-scientific issues were made mostly on the basis of ethical reasoning. The normative arena dominated.

Further research on student views on science-technology-society issues was recently completed as a part of the IEA study (Connelly, Crocker & Kass, 1984). Using a newly created instrument, Views on Science-Technology-Society (VOSTS CDN-2) (Aikenhead, Fleming & Ryan, 1985, 1986), we were able to develop a composite picture of the STS

views of Canadian high school graduates. This represents important benchmark data, for it allows the proposed research to collect university students' views using the same instrument and, by comparison with national data, detect any changes. This is the first objective of the proposed research. If, for example, it should turn out that there are no significant changes in views on STS, it would mean the misconceptions found earlier (Fleming, 1986) will remain part of the repertoire of future science teachers. If, on the other hand, significant changes do occur, the reasons for these changes and the direction of the change must be explored. This is the second objective. Through the use of interviews, the normative views of undergraduates studying science can be explored. Meeting these two objectives could greatly facilitate the design of training programs for STS teachers.

RESEARCH DESIGN

A sample of two hundred students was drawn from classes in the undergraduate chemistry program. Given the paucity of numbers in third and fourth year (nine students and seven students respectively), all these students were used. Of the remaining 184 students, 60 were second year students and 124 were first year students.

Based on demographic data supplied by the students, 25% of them listed their occupational goal as "physical or biological scientist." Six percent listed their occupational goal as "school teacher."

Twenty-nine percent listed their occupational goal as "physician." The remaining forty percent had occupational goals such as "pharmacist", "home economist", "farmer", "interior designer", "agricultural representative", and "entrepreneur".

The researcher was given access to these students during their first laboratory session of the year. During this time, all students were requested to write argumentative responses to four pairs of statements from VOSTS CDN-2. Thus, 800 "pair responses" were obtained. Given that twenty pairs of statements from VOSTS CDN-2 were used, each statement pair had 40 responses. This should allow for theoretical saturation (Glaser & Strauss, 1967). The responses to the statement pairs were analyzed using the method described by Aikenhead, Fleming & Ryan (1985, 1986).

Based on these analyses, base line questions for semi-structured interviews dealing with the interaction of science, technology, and society were created. A stratified random sample of 30 students was chosen to participate in the interviews. These interviews were transcribed and analyzed using methods described by Fleming (1985a) and Goetz & Le Compte (1984).

It is the results of these two sets of analyses that will be discussed in this paper.

RESULTS

VOSTS CDN-2 Results

The student argumentative paragraphs are remarkably similar in content to those of high school graduates examined in earlier research (Fleming, 1986). For example, at first blush undergraduates seem to differentiate clearly between the roles of science and technology and to acknowledge the interrelationship between the two. In all other cases, however, for which such a distinction would be useful, the unified enterprise technoscience dominated their views.

Consider the following VOSTS statements as examples. In each case, the percentage of both high school and undergraduate students for each category of response is given. The similarities are striking.

When VOSTS 11.1/11.2 are examined:

[Table 1 fits here]

If VOSTS 1.1/1.2 are examined:

[Table 2 fits here]

A more complex set of positions is offered in VOSTS 6.1/6.2:

[Table 3 fits here]

Lest one think the "fit" was perfect, VOSTS 7.1/7.2 are offered as a counterpoint:

[Table 4 fits here]

The drop in the number agreeing with mission oriented science was intriguing and was pursued, as will be seen later, in interviews.

As an initial summary, then, there appears to be little, if any,

difference in views on STS between high school graduates and undergraduates studying science. In the case of the latter group, this is correct regardless of age, gender, or number of years of training. Put simply, one could not distinguish the views of a 32 year old female in her fourth year from those of a 19 year old male in his first year. Nothing in the argumentative responses allowed for such a distinction to be made.

The data were next examined to see whether undergraduates who had listed "scientist" as an occupational goal had different views from their fellow students. These findings must be viewed in the light of the research method. Prior to administering VOSTS, the researcher had no idea how many persons of the forty responding to each statement pair would choose "scientist" as their potential occupation. Given that 25% of the sample made this choice, one could infer that 25% of a set of responses should be from this group.

Consider the following cases: VOSTS 11.1/11.2; VOSTS 1.1/1.2:

[Table 5 fits here]

[Table 6 fits here]

The danger, of course, is in inferring too much from such a small number of "future scientists." To probe further, interviews were used.

Interview Results

The interviews were designed to focus on a number of issues. This paper examines two of these. First, the nature of science, with a particular emphasis on the nature of scientific knowledge, was probed.

Secondly, the role of science in our society was examined.

The Nature of Scientific Knowledge

The bulk of the discussion centered on scientific facts. There were two schools of thought, with future scientists and non-scientists fairly evenly distributed through both.

In the first, the creation and verification of scientific facts was the central issue:

Q: Are people doing science also trying to create facts?

A: Yes.

Q: What do you think a fact might be?

A: Alright . . . ah . . . something . . . the . . . a statement, shall we say that within the limits of present technology has been proven with no exceptions found.

Q: How would we know that?

A: It's impossible, because we can never examine every possibility that might contribute to the situation. You can't really prove something to be true you can prove it to . . . you can prove that this factor holds up under those conditions. You can't simulate every condition. So there really is no such thing as a fact 'cause you can never check it against every possible situation and variable that exists.

Q: So what are there then?

A: [Pause]. . . well, there's all the laws, things to which no exceptions have yet been found.

Q: So are scientists in laboratories creating laws?

A: Yes. (3rd year science student)

In response to the question, "What is the source of scientific facts?" we hear:

A: Perception and research. The sunrise, you see in my perception, but lots of people see the same thing, so we agree that the sunrise is a fact. But if only I saw something, it isn't a fact yet, only an isolated incident. I need to get a lunch of people to agree with me.

Q: What if there was another group which agreed with something else?

A: Well, that's OK, but we'd have to work hard to make sure more people agreed with us. Facts are what we make them. (2nd year pre-med).

For the other group, facts simply didn't exist.

Q: What do you think scientific facts are?

A: Oh, there aren't any.

Q: There aren't any.

A: Nope. Only theories. Everything is uncertain, knowledge always changes, so all knowledge is just theoretical. It could be wrong at any time. (2nd year student - premed)

For both groups, the language of the nature of science - facts, theories laws, and hypotheses - appeared to offer refuge. When pushed on one term, switch to another. The first group, did, however, feel that knowledge in science was the result of consensus, a position congruent with current thinking in social studies of science.

The Role of Science in Our Society

As discussed earlier, mission oriented science appeared to be the preferred social role for science. Future scientists, however, did not seem to be so strong in their support of this view. During interviews, the role of science was probed further. A second year chemistry major responded:

Q: Some people say we should only do science if it will benefit our society.

A: Well, I can see why they'd say that but . . . how can you tell if something will help or not. I'd like to just do science - you know, find things out - but I might only get a chance to do that if I can bell people it'll be good for them.

Q: Why would you have to do that?

A: Well, most people wouldn't understand what I was doing, so if I made it sound practical they'd think it was a good idea.

Q: So what do you think science should do for our society?

A: Just find things out - useful things for the future.

A fourth year honors student expressed similar sentiments:

Q: Is science useful for our society?

A: Sure, hey, look at all the improvements we've got through science.

Q: Are you in science to improve our society?

A: Well, it'd be nice if something I found was useful, but when I'm doing science, it's just to see what I'll find out. I guess I don't think much about use.

Q: Some people say we should only support useful science.

A: That's dumb - I mean, maybe it might be useful later - I can see that point . . . I think we tell people it's useful just so they don't get upset and will keep giving us support.

Q: So what should science do for our society.

A: Advance our knowledge, get at more of nature's secrets, that sort of thing.

Science as Faith

The most unexpected development during the interviews with over ninety percent of the students was their unshakable faith in the

training process they were experiencing and in science in general.

With regards to their laboratory sessions:

Q: Are the things you do in labs what a scientist does too?

A: Well, not really. I mean, the techniques I guess and the equipment are probably the same but we're not really doing research. This is just to get us ready to do research - the tools and things.

Q: When will you get to do research?

A: Oh, later, when I know enough techniques. Look, the profs know best when I'm ready. I've got faith in them and the subject, so, ya know, it'll all unfold as it should.

Q: What do you mean by faith?

A: Well, like, I trust my subjects . . . you know . . . this stuff must be right, with all these people believing it, so I know that the longer I stay on, the more things will be revealed to me.

With regards to being a scientist:

Q: Is your program training you to be a scientist?

A: Oh, yeah . . . each year I learn more skills, more knowledge, really good stuff.

Q: This makes you a scientist?

A: Well, there are scientists here who teach us . . . you know, tell us things about the world, getting us ready to explore it on our own. They must be doing these things to make us like scientists.

Q: Do they tell you th [illegible]

A: No, not directl[illegible] [illegible] tell us to have faith and everything will turn out OK - t[illegible] [illegible] give us stuff in its proper time.

Implications

The results indicate that these undergraduates are nearly identical to high school graduates in their understandings of the

relationship between science, technology and society. The number of university science courses taken appears to have made little difference to this understanding.

Drawing prospective science teachers from this group presents STS teacher educators with a challenge: To prepare teachers to deal with STS issues, we must move beyond methods courses to remedy serious deficiencies in knowledge about the social context of science and technology. This task will likely be taken on by facilities of education and not faculties of science.

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TABLE 1

11.1 IN CANADA, SCIENCE AND TECHNOLOGY HAVE LITTLE TO DO WITH EACH OTHER.

11.2 IN CANADA, TECHNOLOGY GETS IDEAS FROM SCIENCE AND SCIENCE GETS NEW PROCESSES AND INSTRUMENTS FROM TECHNOLOGY.

Student Positions

		% of Usable Responses	
		High School Graduates	Undergraduates Studying Science
A.	Scientific research results in improvements in technology and these improvements in turn increase our ability to do scientific research.	74	71
B.	Science is the basis of all technological advances.	13	17
	Unique Responses	13	13

TABLE 2

1.1 SCIENTISTS AND ENGINEERS SHOULD BE GIVEN THE AUTHORITY TO DECIDE WHAT TYPES OF ENERGY CANADA WILL USE IN THE FUTURE (E.G. NUCLEAR, HYDRO, SOLAR, COAL BURNING, ETC.) BECAUSE SCIENTISTS AND ENGINEERS ARE THE PEOPLE WHO KNOW THE FACTS BEST.

1.2 SCIENTISTS AND ENGINEERS SHOULD BE THE LAST PEOPLE TO BE GIVEN THE AUTHORITY TO DECIDE WHAT TYPES OF ENERGY CANADA WILL USE IN THE FUTURE (E.G. NUCLEAR, HYDRO, SOLAR, COAL BURNING, ETC.). BECAUSE THE DECISION AFFECTS EVERYONE, THE PUBLIC SHOULD BE THE ONES TO DECIDE.

Student Positions

		% of Usable Responses	
		High School Graduates	Undergraduates Studying Science
A.	Scientists and engineers have training and facts which give them a better understanding of the issue.	57	53
B.	Scientists and engineers have the training and facts which give them a better understanding of the issue, but the public should be consulted.	14	15
C.	All groups, not just scientists and engineers, must be involved with decisions which affect our society.	16	14
D.	There are other views to consider rather than just the views of scientists and engineers.	2	---
E.	Scientists and engineers should be involved in giving advice, but the ultimate decision lies with the people.	7	18
F.	Scientists and engineers have idealistic and narrow views on these issues. The public serves as a check on the scientists' inattention to consequences.	2	---
	Unique responses	2	---

TABLE 3

6.1 ALTHOUGH ADVANCES IN SCIENCE AND TECHNOLOGY MAY IMPROVE LIVING CONDITIONS IN CANADA AND AROUND THE WORLD, SCIENCE AND TECHNOLOGY OFFER LITTLE HELP IN RESOLVING SUCH SOCIAL PROBLEMS AS POVERTY, CRIME, UNEMPLOYMENT, OVERPOPULATION, AND THE THREAT OF NUCLEAR WAR.

6.2 SCIENCE AND TECHNOLOGY OFFER A GREAT DEAL OF HELP IN RESOLVING SUCH PROBLEMS AS POVERTY, CRIME, UNEMPLOYMENT, OVERPOPULATION, AND THE THREAT OF NUCLEAR WAR.

Student Positions

		% of Usable Responses	
		High School Graduates	Undergraduates Studying Science
A.	These social problems are the price we pay for advances in science and technology, i.e. science and technology only make these problems worse.	22	23
B.	It is not a question of science and the technology helping, but rather it is a question of people using science and technology wisely.	19	5
C.	It is hard to see how science and technology could help to resolve these social problems, other than to raise the standard of living.	9	8
D.	Science and technology can help resolve some social problems but not others.	16	---
E.	Science and technology will solve these problems as long as proper support is provided.	15	19
	Unique responses	19	---

TABLE 4

7.1 THE CANADIAN GOVERNMENT SHOULD GIVE SCIENTISTS RESEARCH MONEY ONLY IF THE SCIENTISTS CAN SHOW THAT THEIR RESEARCH WILL IMPROVE THE QUALITY OF LIVING IN CANADA TODAY.

7.2 THE CANADIAN GOVERNMENT SHOULD GIVE SCIENTISTS RESEARCH MONEY TO EXPLORE THE UNKNOWNS OF NATURE AND THE UNIVERSE.

Student Positions

		% of Usable Responses	
		High School Graduates	Undergraduates Studying Science
A.	Money should only be spent on research that is directly related to specific beneficial goals like helping our environment, health, or agriculture.	48	28
B.	Even though science tries to improve the quality of life, it is often impossible to tell ahead of time whether the research will be beneficial or not. Thus you have to invest money in scientific research.	28	25
C.	The government should fund scientific research because it always has an impact, directly or indirectly, on society.	3	10
D.	The government should fund scientific research for no other reason than to investigate the workings of our world.	13	8
	Unique responses	7	---

TABLE 5

11.1 IN CANADA, SCIENCE AND TECHNOLOGY HAVE LITTLE TO DO WITH EACH OTHER.

11.2 IN CANADA, TECHNOLOGY GETS IDEAS FROM SCIENCE AND SCIENCE GETS NEW PROCESSES AND INSTRUMENTS FROM TECHNOLOGY.

Student Positions

		% of Usable Responses	
		Future Scientists	Others
A.	Scientific research results in improvements in turn increase our ability to do scientific research.	83	63
B.	Science is the basis of all technological advances.	17	20
	Unique responses	---	17

TABLE 6

1.1 SCIENTISTS AND ENGINEERS SHOULD BE GIVEN THE AUTHORITY TO DECIDE WHAT TYPES OF ENERGY CANADA WILL USE IN THE FUTURE (E.G. NUCLEAR, HYDRO, SOLAR, COAL BURNING, ETC.) BECAUSE SCIENTISTS AND ENGINEERS ARE THE PEOPLE WHO KNOW THE FACTS BEST.

1.2 SCIENTISTS AND ENGINEERS SHOULD BE THE LAST PEOPLE TO BE GIVEN THE AUTHORITY TO DECIDE WHAT TYPES OF ENERGY CANADA WILL USE IN THE FUTURE (E.G. NUCLEAR, HYDRO, SOLAR, COAL BURNING, ETC.). BECAUSE THE DECISION AFFECTS EVERYONE, THE PUBLIC SHOULD BE THE ONES TO DECIDE.

Student Positions

		% of Usable Responses	
		Future Scientists	Others
A.	Scientists and engineers have the training and facts which give them a better understanding of the issue.	50	53
B.	Scientists and engineers have knowledge of the issue and can make better decisions than bureaucrats and companies, both of which have vested interests.	---	---
C.	Scientists and engineers have the training and facts which give them a better understanding of the issue, but the public should be consulted.	---	13
D.	All groups, not just scientists and engineers, must be involved with decisions which affect our society.	25	14
E.	There are other views to consider rather than just the view of scientists and engineers.	---	---
F.	Scientists and engineers should be involved in giving advice, but he ultimate decision lies wit. the people.	25	20
G.	Scientists and engineers have idealistic and narrow view on these issues. The public serves as a check on the scientists' inattention to consequences.	---	---
	Unique responses		